Increasing Soybean Yields: Brazil's Challenges

By Eros Francisco, Gil Câmara, Valter Casarin, and Luis Prochnow

Average soybean yield has increased over recent decades in many areas of the world, but a plateau seems to have been reached in some situations, Brazil being a typical case. This article summarizes the main reasons why this has happened in the world's second largest soybean producing country, and what farmers need to overcome to break the current barrier. Also, a few lessons on general common practices contributing to high yields in the U.S. are outlined.

Brazilian soybean production has the potential to become the largest in the world. In 2013, its production ranked second at 81.5 million t (CONAB, 2013). The U.S. led with 88.6 million t (USDA, 2013) while other major producers include Argentina, China and Índia (FAO, 2013). Since the 1990s there has been a significant increase in land cultivated to soybean in Brazil, especially due to the development of new areas in the Midwest (**Figure 1**).

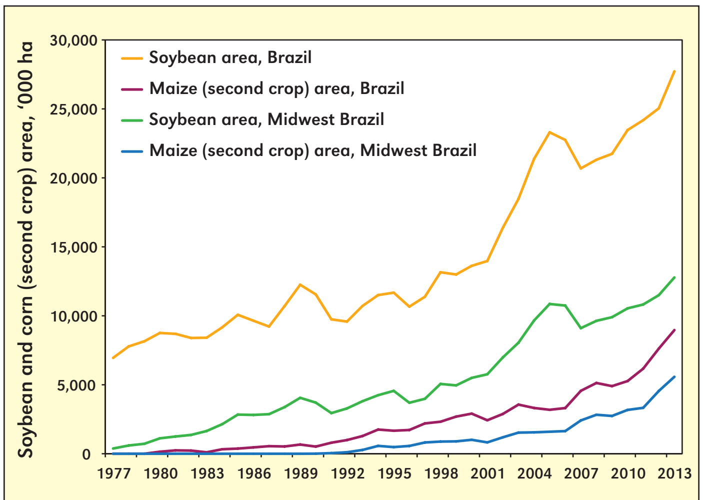

Figure 1. Soybean and maize second crop cultivated land in Midwest Brazil and Brazil from 1977 to 2013. Source: Conab, 2013.

Favorable soil and climatic conditions, genetic improvement, government loans, adoption of technology, and intensive farmer effort have all contributed to the success of soybean production in the Brazilian Savannah (Cerrado). Nevertheless, soybean production systems face real challenges including adverse weather (drought or flooding), new disease and pest issues, and the adoption of sub-par management practices.

Soybean production systems in Brazil were basically unchanged until the late 1990s, with soybean grown mainly under conventional tillage systems from early November to late March or April. After 2000, farmers started to seed earlier in the season (October), adopt no-tillage rapidly, and began growing cover crops after soybean harvest. This system has spread and currently about 50% of the soybean area in the Cerrado during the summer turns into maize second crop, 5% turns to cotton second crop, and other areas are covered with different grain or cover crops, such as sorghum, beans, millet, brachiaria grass, and sunn hemp.

The technological evolution of agriculture in the Cerrado during the 1990s was crucial to reach the current average soybean yield of 3,000 kg/ha. Genetic improvements were able to deliver new varieties adapted to low latitudes, and resistant to *Phytophtora* (Stem Canker) and *Heterodora glycines* (cyst nematode). New fungicide/insecticide molecules were developed as well as more efficient strains of *Bradyrhizobium japonicum*, all in parallel with better nutrient management practices.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; C = carbon; B = boron; Mo = molybdenum; Co = cobalt.

The strong expansion of cultivated area has been beneficial in many aspects, but is also creating some challenges: (i) soil fertility management in a new agriculture frontier, especially with sandy soils; (ii) crop disease management due to the introduction of Asian Rust (*Phakopsora pachyrhizie*) in 2001; (iii) soil compaction in old no-till production fields; (iv) high population of nematodes, especially the soybean cyst nematodes and pratylenchus nematodes (*Pratylenchus brachyurus*); and (v) new pests (**Figure 2**).

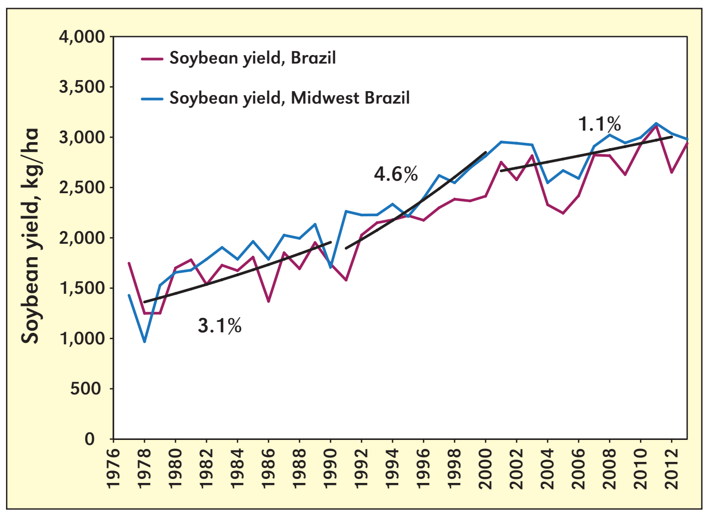

Figure 2. Soybean yield increases in Midwest Brazil and Brazil from 1977 to 2013. Source: Conab, 2013.

Agronomic Challenges for High Yielding Soybean Systems

Early Seeding and Short Maturity Cultivars

Soybean grain yield is positively correlated with variety maturation cycle when other factors are kept the same (latitude, seeding time and crop management). Therefore, under the same soil and weather conditions, long cycle soybean groups tend to be more productive than short cycle groups because of higher leaf area index to intercept light and fix C, and also more extensive root systems to take up more nutrients, fix N, and accumulate greater amounts of biomass. Drastically advancing time of seeding leads to a growing season with shorter days, which tends to depress yields even more. Some reports indicate a 5 to 10% loss in yield depending on the interaction between crop variety and seeding time.

Biological N Fixation

Nitrogen is a critically important nutrient for soybean. Nitrogen levels in the grain range from 4.5 to 6.5%, while the stover is generally 3.0% N. Soybean generally requires about 240 kg N/ha to yield 3,000 kg/ha (Hungria et al., 2001). Most of this N is supplied by biological fixation (BNF).

To study soybean system efficiency, Oliveira Jr. et al. (2010) used results for his soybean N budget from Alves et al. (2006). An average yield of 3,244 kg/ha was associated with 228 kg N/ha in the total dry matter yield, of which 194 and 35 kg N/ha came from BNF and the soil, respectively. With a total grain uptake of 183 kg N/ha, the net N budget was only 10 kg/ha.

The authors call attention to factors that depress BNF such as: (i) Mo and Co availability, which has a direct relationship with soil pH and, therefore, liming helps to supply such nutrients to plants; (ii) soil compaction, which negatively impacts soil aeration; and (iii) soil temperature. Important soil management practices such as liming, incorporation of P into the soil profile, and proper crop rotation all promote a good environment for vigorous soybean root systems, while soil compaction and high acidity greatly impact BNF and plant growth.

Soybean root system with (top) and without nodules (bottom) in response to soil management that promotes biological N fixation.

High soil temperatures also have a large impact on BNF. The ideal temperature for *Bradyrhizobium* development is around 25 to 30°C (Bizarro, 2008). **Table 1** shows temperatures observed in a high clay soil (65% clay) during a sunny afternoon in a soybean field at an early growth stage. Temperature of the seedbed zone (2 to 3 cm) was very high in plots without crop residue (60°C or 140°F), while no-till plots with crop residue had much lower temperatures. The impact of high temperatures on BNF can be even more detrimental in exposed sandy soils.

Table 1. Soil temperature (°C) in response to soil management and depth.

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Soil management	0	2	4	6	8
No-till system	41.0a	34.2a	32.9a	32.5a	32.1a
Conventional tillage	60.2b	45.2b	42.9b	41.2b	40.0b

Means followed by the same letters do not differ within columns (p = 0.05).
Source: Research Foundation MT, 2012 (unpublished data).

Broadcast P Application

In past years, there has been a large-scale adoption of broadcasting P fertilizers in Brazil. There is a lack of official statistics, but a short survey made by IPNI Brazil Program during a national webinar showed that 35% of the attendees broadcasted P over their entire farm, while 51% use the practice on at least half of their farm.

Broadcasting P is not a new technique, but its general adoption is more associated with the need to speed up the seeding process due to changes in the production systems (i.e., relying on early seeding dates and harvesting as a way to escape Asian Rust) and also, to increase the area available for a maize second crop.

Some studies have shown high-yielding soybean with the broadcasting of soluble P fertilizers (Kappes et al., 2013; Oliveira Jr. et al., 2011; Souza and Lobato, 2003). However, Oliveira Jr. and Castro (2013) emphasized caution since (i) even in high fertility soils banded application has shown yield increases compared to broadcast application, and (ii) continuous broadcast application of P fertilizer in no-till systems will lead to the formation of a gradient of available soil P within the profile since P is not mobile in most soils. The authors showed, based on a two year study comparing P rates and placement, that there is a positive relationship between soybean yield increase and higher available soil P in the subsurface (10 to 20 cm) layer (**Figure 3**). The adoption of broadcast application of P fertilizer needs careful evaluation of the soil chemical conditions in order to benefit soybean yield. Adoption of the practice in the absence of this information does not meet with agronomic recommendations.

Soybean on Sandy Soils

Sandy soils (< 15% clay) in Brazil are generally not recommended for annual cropping due to limitations in nutrient availability, water holding capacity, and erosion susceptibility. Nevertheless, the expansion of cultivated land in Brazil made farming these soils an important reality. Grain production on sandy soils is a great economic challenge. The most limiting nutrients in these soils include the most mobile, which are N, K, B, and S.

Again, with no crop residue on the surface, these soils are exposed to very high temperatures with great consequences for BNF. Nitrogen deficiency symptoms are often visible in very early growth stages (V_2/V_3). The conservation of crop residue promotes nutrient cycling, which is crucial for sustainability in sandy soils, and particularly affects the K supply to plants and makes the timing of K application crucial. Soybean plants

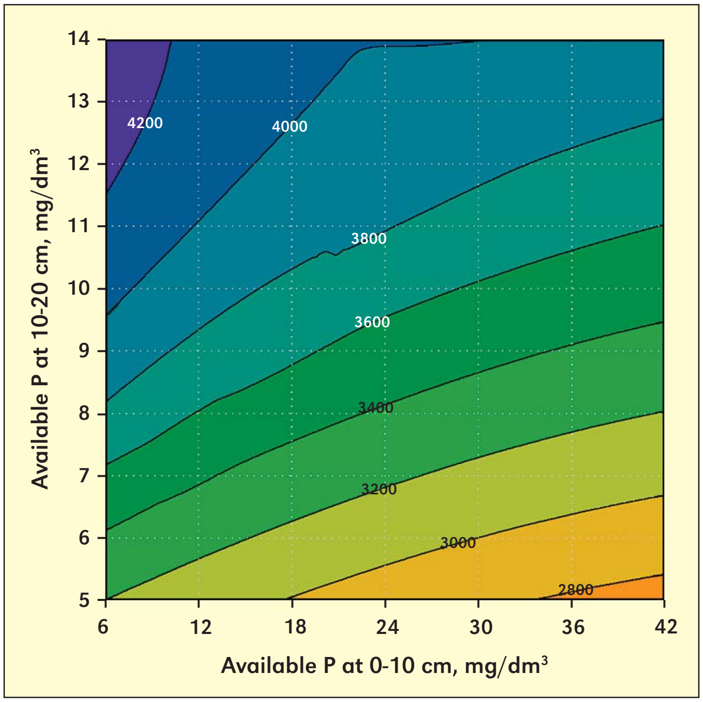

Figure 3. Soybean yield in response to available P (Mehlich 1) in the 0 to 10 cm and 10 to 20 cm soil layers. Source: Oliveira Jr. and Castro, 2013.

Deficiency symptoms of N (top) and K (bottom) in soybean plants grown on exposed, sandy soils.

can show K deficiency symptoms in early growth stages where fertilizer application is postponed.

Early Desiccation for an Early Harvest

Early harvest of soybean fields in Midwest Brazil is increasingly attractive for farmers seeking a second crop in the season, which is mostly maize, but has led growers to make wrong decisions regarding the timing of soybean desiccation. This technique was developed to control weeds and homogenize maturity in plants suffering with green stems or leaf retention. According to EMBRAPA (2011), desiccant application before R_7 growth stage (beginning of maturity) can cause dramatic decreases in yield.

Final Considerations

High soybean yields in Brazil are common in regions where the agronomic practices are used correctly. Nevertheless, we consider that yields between 3.6 to 4.0 t/ha are likely 75 to 85% of attainable yield, and therefore some important questions are raised. How far are we from maximum yield? How much of the complex set of interactions between the cropping system and the production environment is understood?

Ecological intensification of the cropping system represents a huge advantage for regions of the world where two or more crops can be grown in a season, but it is highly dependent on a fast operational system to crop vast areas in a short time. It seems that in some cases agronomic practices hold a second place priority in favor of the overall scale of production. BC

High Soybean Yields in the U.S.

Dr. Valter Casarin, Deputy Director of the IPNI Brazil Program, recently toured the main soybean regions in U.S. looking for common practices leading to high yields. Following is a list of his main observations, which might be of use in other parts of the world.

Cultivar selection: farmers carefully select cultivars based especially on maturity cycle, resistance to diseases and pests, and consistency in yield through time.

Planting date: The target is to seed as early as possible and take advantage of water availability, but late enough in the season as to avoid frost.

Plant population: In general, seeding in narrow rows is leading to higher yields due to more rapid covering of the soil, higher interception of solar radiation, and less problems with weeds.

Weed control: Several field experiments in different regions define the best herbicides for each cultivar. In some situations, weed control can significantly decrease nematodes and some diseases and insects.

Nitrogen in soybean: Careful attention is necessary to prevent a decrease in BNF by the presence of too much available soil N, but in some regions, especially in sandy soils, farmers do apply some supplemental N during the crop's late development stage (R_3).

Soil fertility: Higher yields demand close attention to soil fertility status to avoid a lack of proper nutrient supply to plants. Some advantages have been noticed with the application of banded P to soils, even when availability is medium to high. Sulfur and micronutrient availability needs also to be carefully evaluated.

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References

Alves, B.J.R., L. Zotarelli, F.M. Fernandes, J.C. Heckler, R.A.T. Macedo, R.M. Boddey, C.P. Jantalia, and S. Urquiaga. 2006. Pesquisa Agropecuária Brasileira, v.41, n.3, pp.449-456.

Bizarro, M.J. 2008. Tese (Doutorado) - Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre. 97p.

CONAB, 2013. Séries históricas: Soja. http://www.conab.gov.br/conteudos.php?a=1252&t=2&Pagina_objcmsconteudos=3#A_objcmsconteudos. Accessed Sept. 10, 2013.

EMBRAPA, 2011. Londrina: Embrapa Soja; Embrapa Cerrados; Embrapa Agropecuária Oeste. (Embrapa Soja. Sistemas de Produção, 13)

FAOStat, 2013. http://faostat3.fao.org/faostat-gateway/go/to/home/E. Accessed Sept. 10, 2013.

Hungria, M., R.J. Campo, and I.C. Mendes. 2001. Embrapa Soja, Circular Técnica, 35.

Kappes, C., L. Zancanaro, and E.A.B. Francisco. 2013. *In*: Reunião de Pesquisa de Soja da Região Central do Brasil, 33, Londrina, PR. Resumos expandidos. Brasília: Embrapa.

Oliveira Jr., A., and C. Castro, 2013. *In*: XII Workshop CTC Agricultura, Rio Verde, GO.

Oliveira Jr., A., L.I. Prochnow, and D. Klepker. 2011. Scientia Agricola, v.68, pp. 376-385.

Oliveira Jr., A., C. Castro, D. Klepker, and F.A. Oliveira. 2010. *In*: L.I. Prochnow, V. Casarin, S.R. Stipp (eds.). Boas práticas para uso eficiente de fertilizantes: culturas. (v.3). IPNI – Brasil, Piracicaba, SP. pp.1-38.

Sousa, D.M.G., and E. Lobato. 2003. Informações Agronômicas, No. 102, IPNI - Brasil. Encarte Técnico. Piracicaba, SP.

USDA, 2013. Crop Production. http://usda01.library.cornell.edu/usda/current/CropProd/CropProd-09-12-2013.pdf. Accessed Sept. 12, 2013.

IPNI Crop Nutrient Deficiency Photo Contest—New Rules for 2014

The International Plant Nutrition Institute (IPNI) is continuing its sponsorship of its plant nutrient deficiency photo contest during 2014 to encourage field observation and increase understanding of crop nutrient deficiencies. However, this year our contest features some important changes:

1. In addition to the four nutrient categories (N, P, K and Other Nutrients - secondary and micronutrients), we have added a new **"Feature Crop"** category—in 2014 we are focused on **Hay and Forage Crops**.

Like previous years, we are ready to receive images for all crops from avocado to zucchini, but if you have a great photo of a nutrient deficiency in a forage crop, now is the time to share it.

2. Our new list of prizes is as follows:

- US$300 First Prize and US$200 Second Prize for Best Feature Crop Photo.
- US$150 First Prize Awards and US$100 Second Prize Awards within each of the N, P, K and Other Nutrient categories
- In addition, all winners will receive the most recent copy of our USB Image Collection. For details on the collection please see http://ipni.info/nutrientimagecollection

3. Specific supporting information is required (in English) for all entries, including:

- The entrant's name, affiliation and contact information.
- The crop and growth stage, location and date of the photo.
- Supporting and verification information related to plant tissue analysis, soil test, management factors and additional details that may be related to the deficiency.

"We hope the competition will appeal to practitioners working in the field," said IPNI President Dr. Terry Roberts. "Researchers working under controlled plot conditions are also welcome to submit entries. We encourage crop advisers, field scouts and others to photograph and document nutrient deficiencies in crops."

Photos and supporting information can be submitted until December 12, 2014 (Friday, 5pm EST) and winners will be announced in January of 2015. Winners will be notified and results will be posted at www.ipni.net. BC